

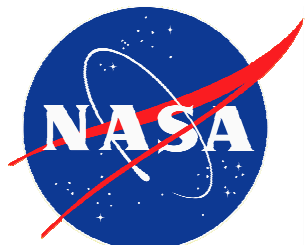


Laser-Induced Latchup Screening and Mitigation in CMOS Devices – an Assessment

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Affiliations:

Naval Research Laboratory

QSS Group., Inc., Seabrook

The Boeing Company,

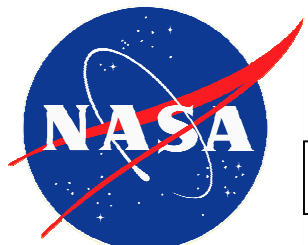
National Semiconductor

NASA Goddard Space Flight Center

NASA Office of Logic Design

SGT/NASA GSFC

Sandia National Labs



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Why is Latchup an Issue?

- A single latchup event can compromise an entire mission
- NASA program requirement: **no destructive latchup for LETs < 80 MeV·cm²/mg.**

Three classes:

- Damage
 - Obvious consequences
- No Damage
 - downtime - may or may not be acceptable
- Latent Damage
 - can compromise operational lifetime of mission

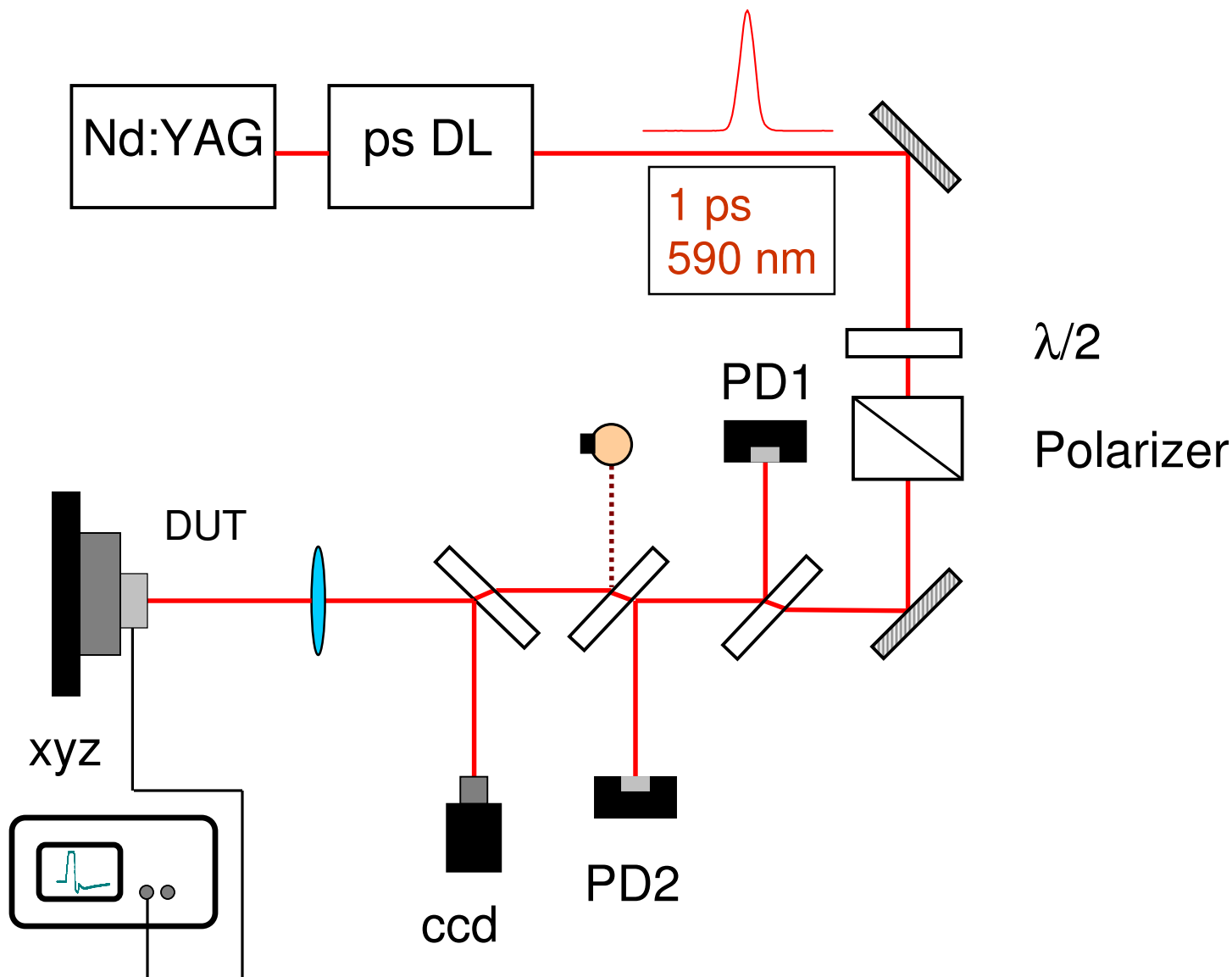
Latchup Testing Using Heavy Ions at Accelerators

- **Standard Approach** is to test for latchup using heavy ions at accelerators.
- The **limited access** to accelerators is a problem.
- Over the past decade, the pulsed laser has been developed as a **complementary** laboratory tool useful for:
 - SEL screening
 - Identifying SEL-sensitive areas (modify design)
 - Validating mitigation approaches.

Pulsed Picosecond Laser

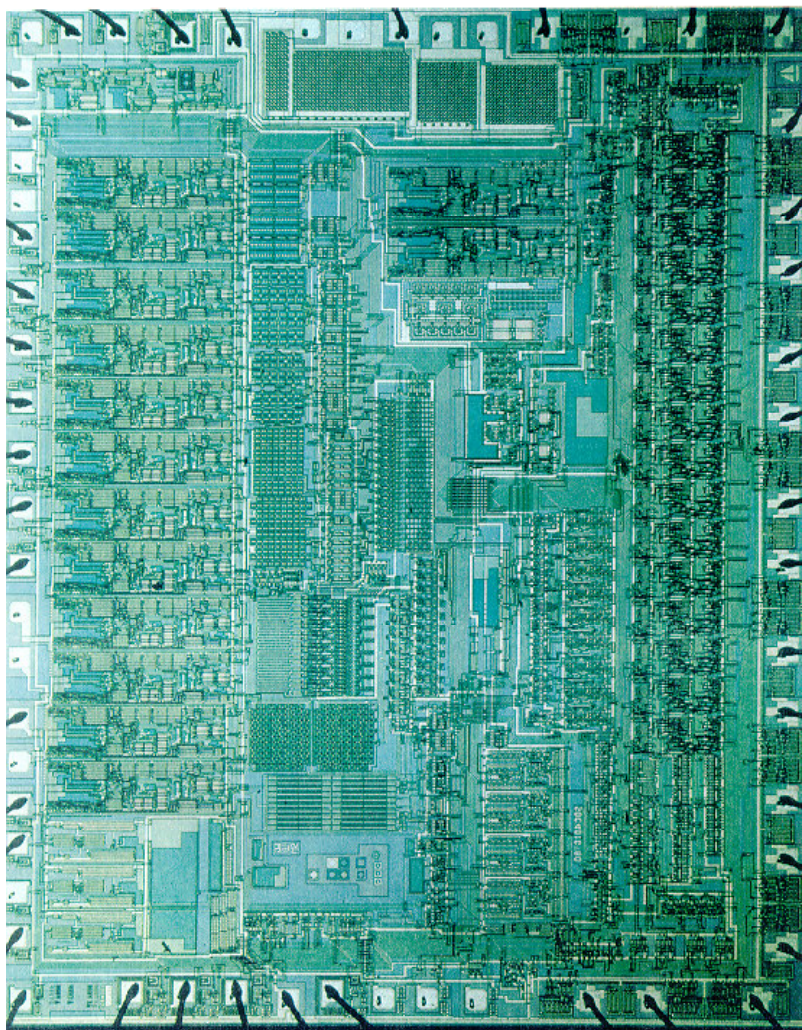
- Indispensable tool for SEE characterization
- A pulsed laser can inject:
 - a well-characterized **quantity of charge**
 - in a well-defined **location**
 - at a well-defined **time**
 - with a well-defined **charge-deposition profile**
- Today: Application to **Latchup Screening and Characterization**

Pulsed Laser SEE Experiment



1. Comparison of Latchup Sensitivity in Two Resolver-to-Digital Converters.

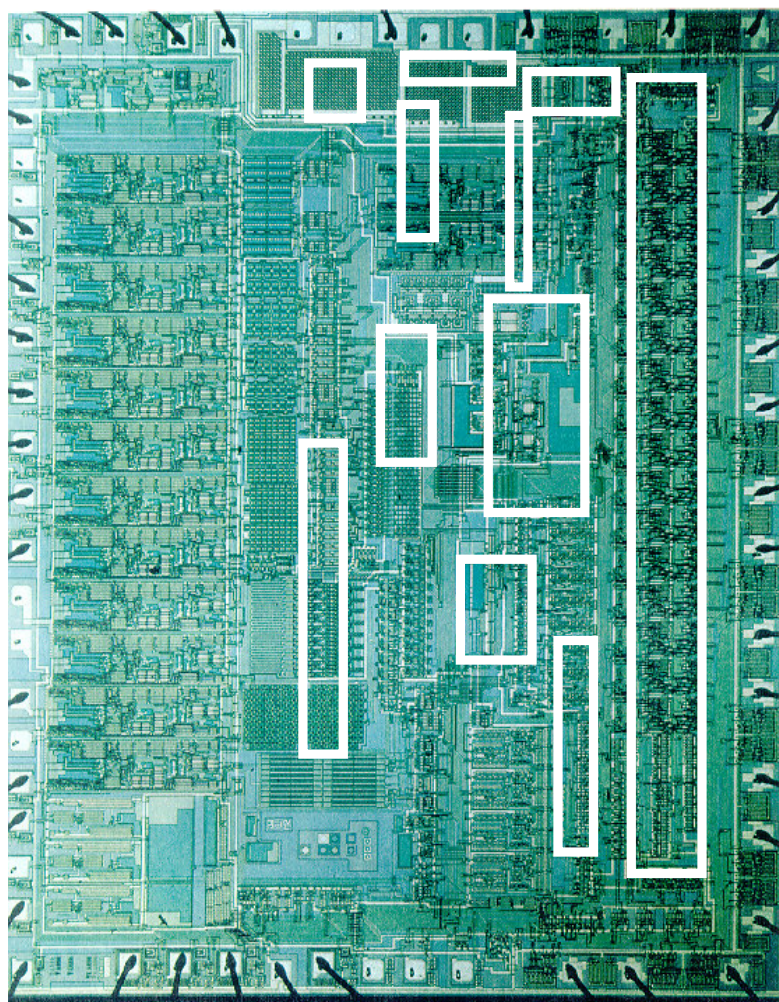
Latch-Up Screening of COTS Parts for Space Missions



- Two **Resolver-to-Digital Converters** were screened for latchup for a NASA space mission.

DDC RDC19220

Latch-Up Screening of COTS Parts for Space Missions



- The latch-up sensitive areas for one of the parts are shown here.
- LET threshold $\sim 8 \text{ MeV.cm}^2/\text{mg}$.
- Based solely on these laser results, this part was **eliminated from consideration** for this and future NASA missions.

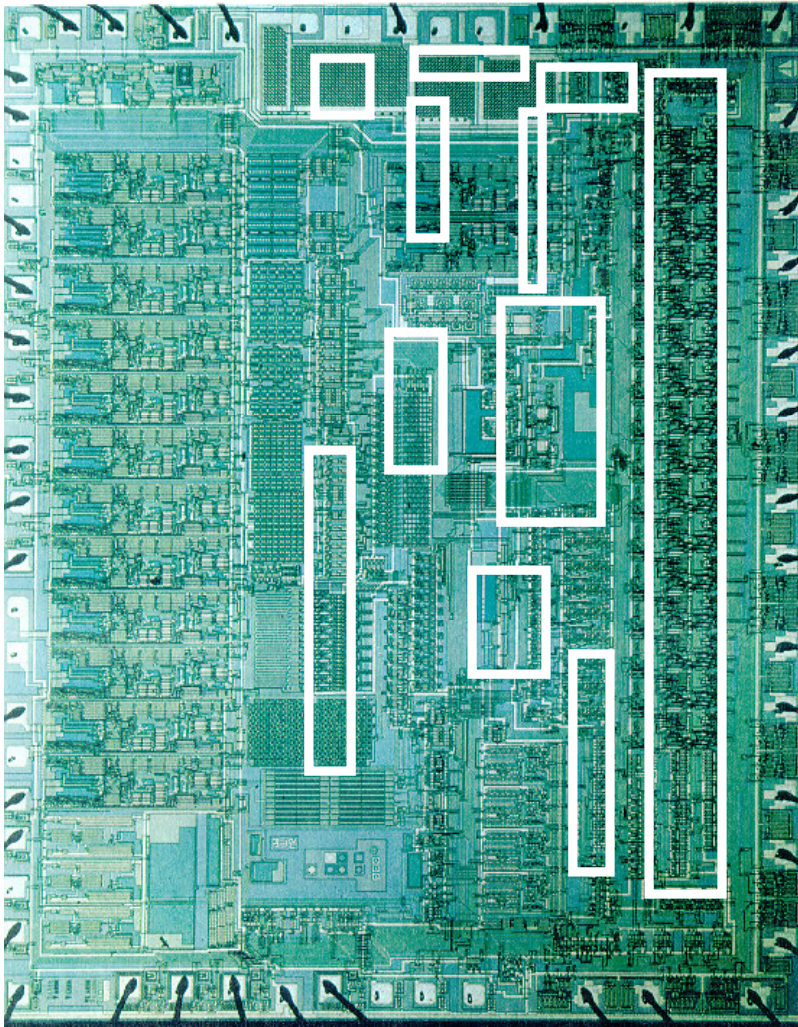
*Buchner, et al., TNS, **46**, 1445 (1999).*

(DDC RDC19220)

SEL sensitive areas in COTS RDC

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Latch-Up Screening of COTS Parts for Space Missions



- The latch-up sensitive areas for one of the parts is here
- LET threshold $\sim 8 \text{ MeV.cm}^2/\text{mg}$
- Based solely on these laser results, this part was eliminated from consideration for this and future NASA missions
- The other part (AD2S80) was found to be latch-up free and deemed acceptable for the mission in question.
- Results confirmed later with heavy-ion experiments.

Latch-Up Screening of COTS Parts for Space Missions

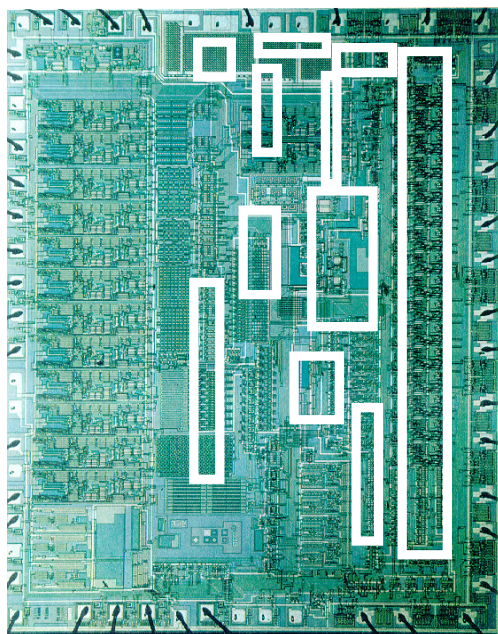
- Laser gives an upper bound for threshold
- This example:

2.8 pJ latchup threshold

1.4 pC deposited charge

$LET_{th}: 8 \text{ MeV}\cdot\text{cm}^2/\text{mg}$

→ This is an SEL sensitive device



Latch-Up Screening of COTS Parts for Space Missions

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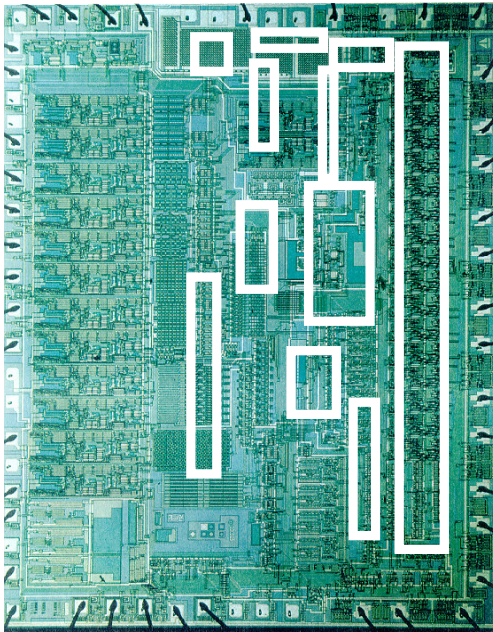
- Another Example:

$LET_{th}: 12.5 \text{ pC (75 MeV}\cdot\text{cm}^2/\text{mg)}$

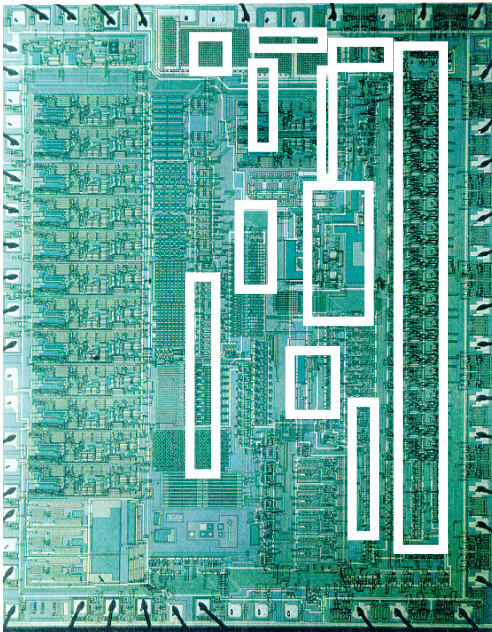
This means: $LET_{th} \leq 75 \text{ MeV}\cdot\text{cm}^2/\text{mg}$

Could be 25 $\text{MeV}\cdot\text{cm}^2/\text{mg}$, ...

Rational decisions required



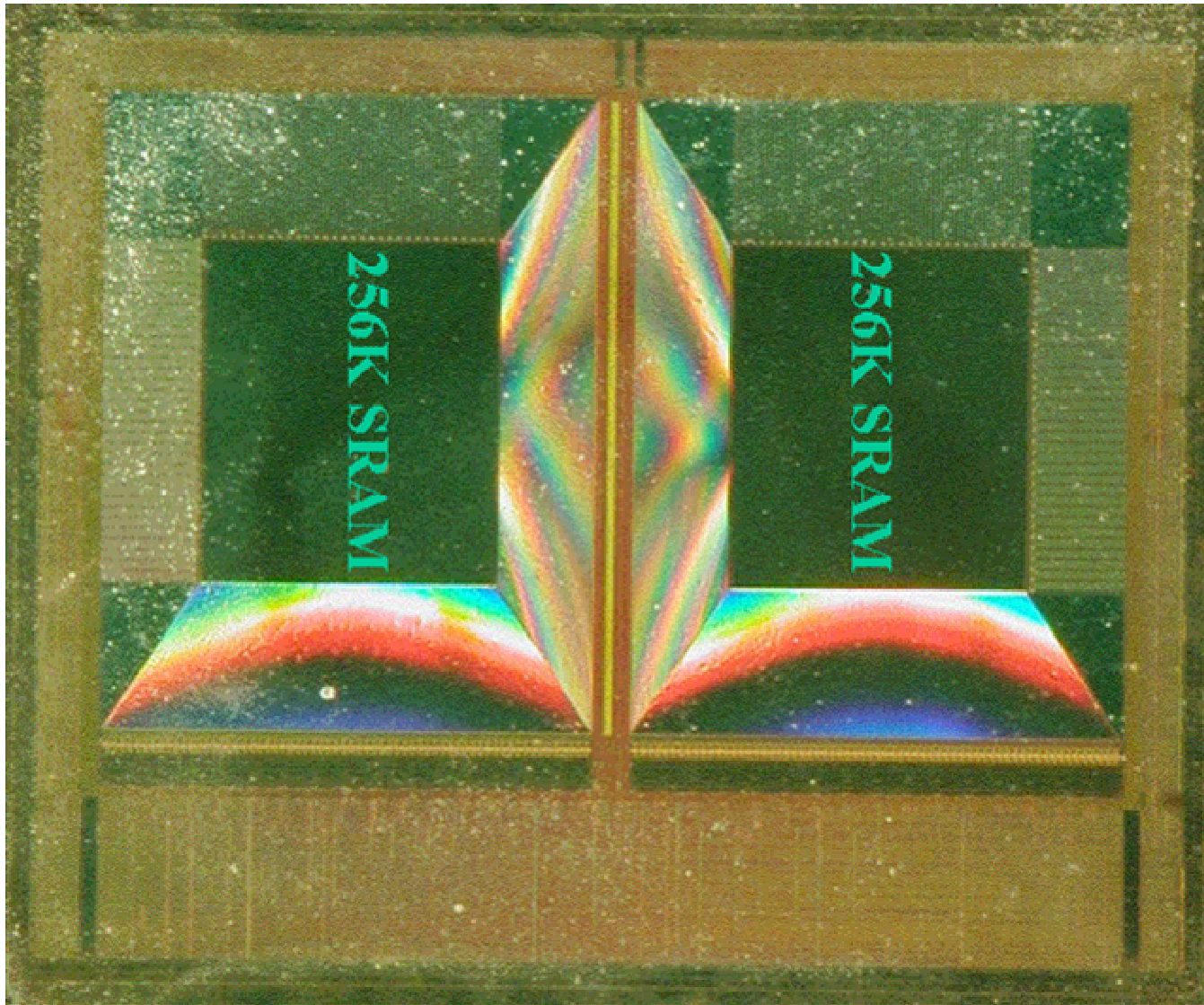
Latch-Up Screening of COTS Parts for Space Missions



- One more practical point regarding the laser application
- To date we have not yet found a part that exhibits latchup with heavy ions that we could not latch up with the laser
- Reason:
 - Laser PE can be increased to very large values
 - 400 pJ (200 pC)
 - 1200 MeV·cm²/mg!!
 - For example: if only 10% of the light reaches the sensitive volume, this still corresponds to an effective LET of 120 MeV·cm²/mg

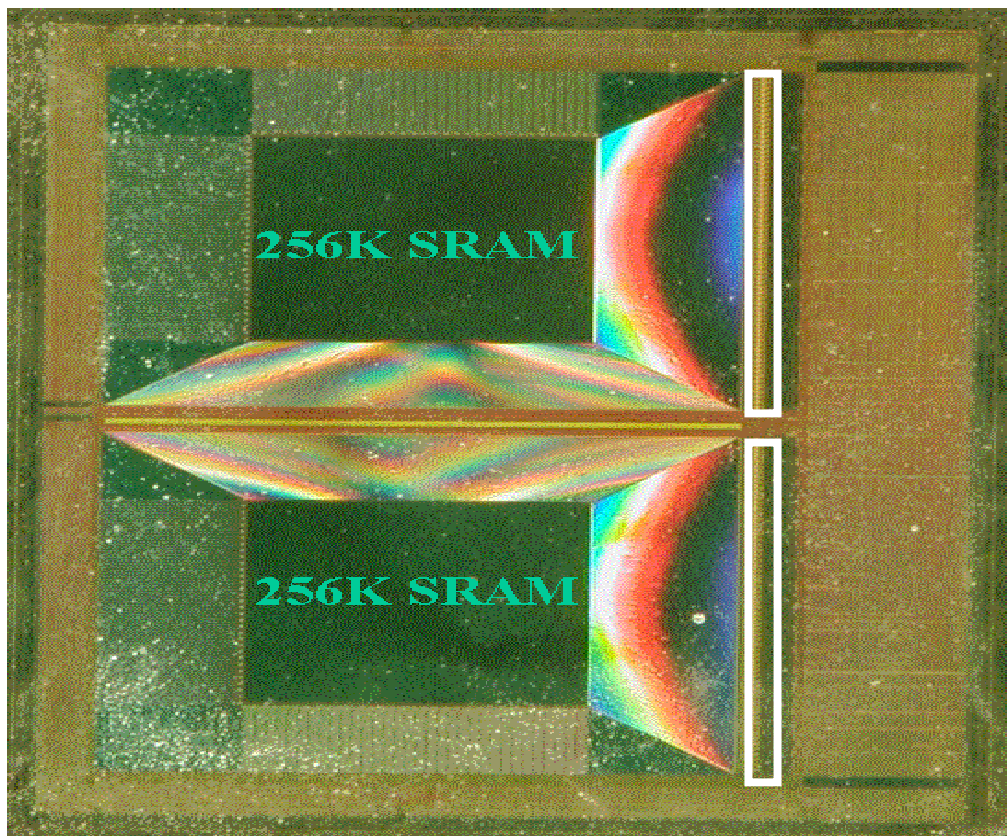
2. LSI SRAM – Identification of Latchup Sensitive Areas

LSI LXA0387 512 Kbit SRAM



- Test chip
- HI tests reveal latchup above $29 \text{ MeV}\cdot\text{cm}^2/\text{mg}$
- Pulsed laser used to identify the sensitive area, determine cross section, and see if damage could be induced

LSI LXA0387 512 Kbit SRAM

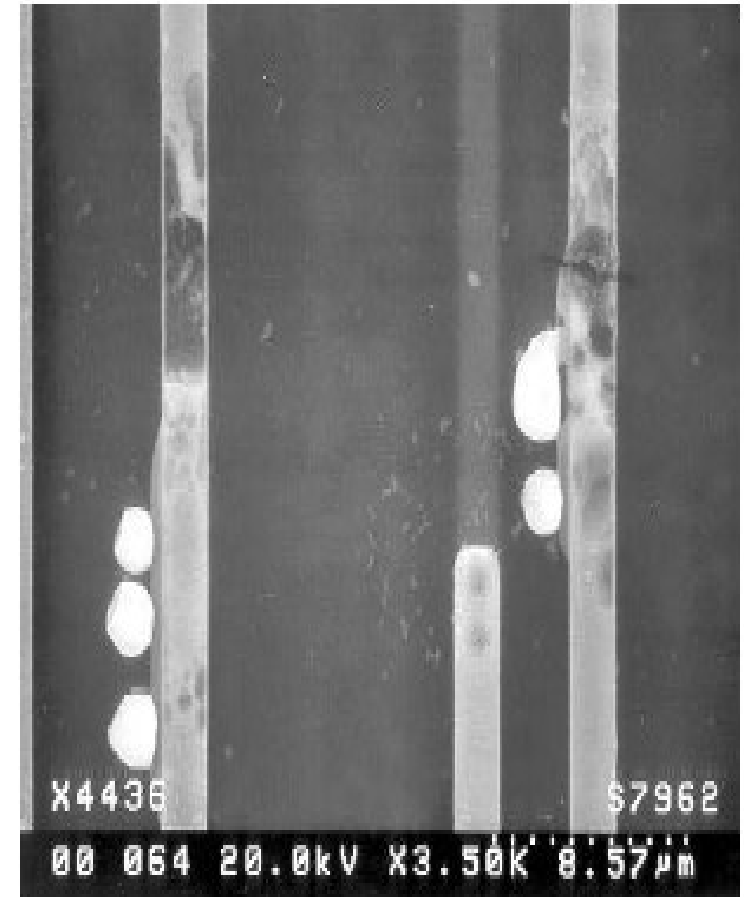


- No latchup in memory circuitry – agrees with latchup tests on other devices.
- SEL sensitive regions limited to **control circuitry**
- Small cross section.
- The observed latchups were **non-destructive**:
 - Maximum SEL current 160 mA
 - **Power cycling recovers full device performance**
- Latent damage not considered in this analysis.

3. Latent Damage

Latent Damage

- First reported in 2002: “*Latent Damage From Single-Event Latchup*”, H.N. Becker, T.F. Miyahira, and A.H. Johnston.
- Permanent structural damage in metal or dielectric caused by latchup currents
- May or may not be observable
- Use of pulsed laser to produce SEL aided in identifying damage sites
- Permanent structural damage may eventually cause device failure



Serious concern for program managers

Latent Damage: Elpida 256 MBit SDRAM

- Heavy ion Testing: Latchup threshold between 54 MeV·cm²/mg and 65 MeV·cm²/mg
- Program managers concerned about latent damage
- Performed HI tests to induce latchup
- Followed by accelerated life test (125 C for 1000 hrs)
 - No evidence of diminished lifetime
- Parts acceptable for future NASA missions

Role of Pulsed Laser in Latent Damage

- Surface scan for latchup – induces SELs in all areas.
- Identify presence of latent damage
 - Infrared camera
 - Optical/electron microscope
 - Accelerated life test (1,000 hours @ 125 C).
- Two open issues regarding multiple latchups:
 - Do multiple latchups at same site produce more damage?
 - Do multiple latchups at different sites followed by accelerated life test give a fair picture of situation during mission where only few latchups may occur?

4. National Semiconductor LVDS Driver

National Semiconductor DS90C031 LVDS

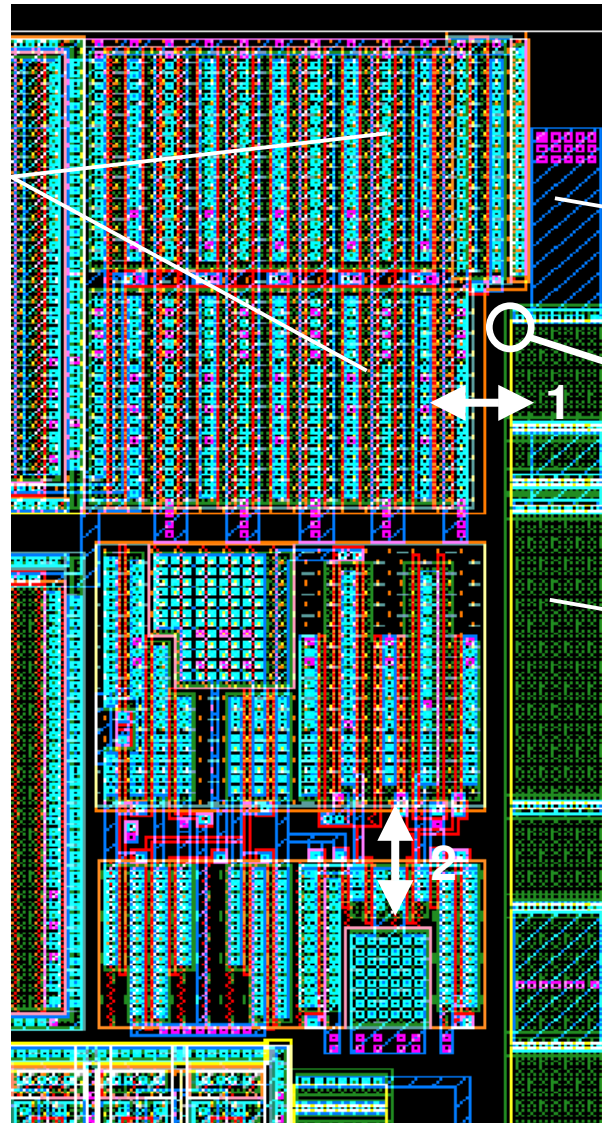
Original Design

- LVDS Quad differential line driver designed into recent **GPS upgrade program**
- Unanticipated **latchup sensitivity observed** in HI testing (*NASA*)
- **Unacceptable** for mission requirements; threatened to delay launch date (**big \$\$\$**)
- Pulsed laser SEL evaluation (*NRL*) revealed sensitivity **localized to a small region** → redesign possible
- Redesigned (*Boeing*) → refabricated (*NS*) → retested (*NASA*)
- **No Latchup observed in redesigned part**
- Launch on schedule

National Semiconductor DS90C031 LVDS

Original Design

Drive Transistor



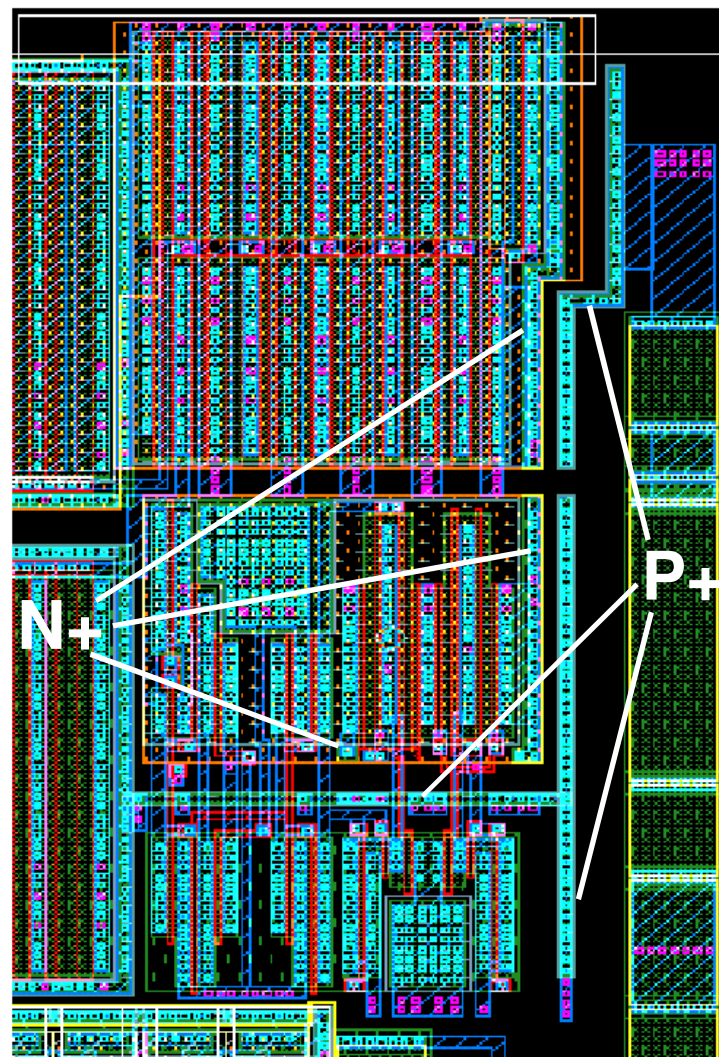
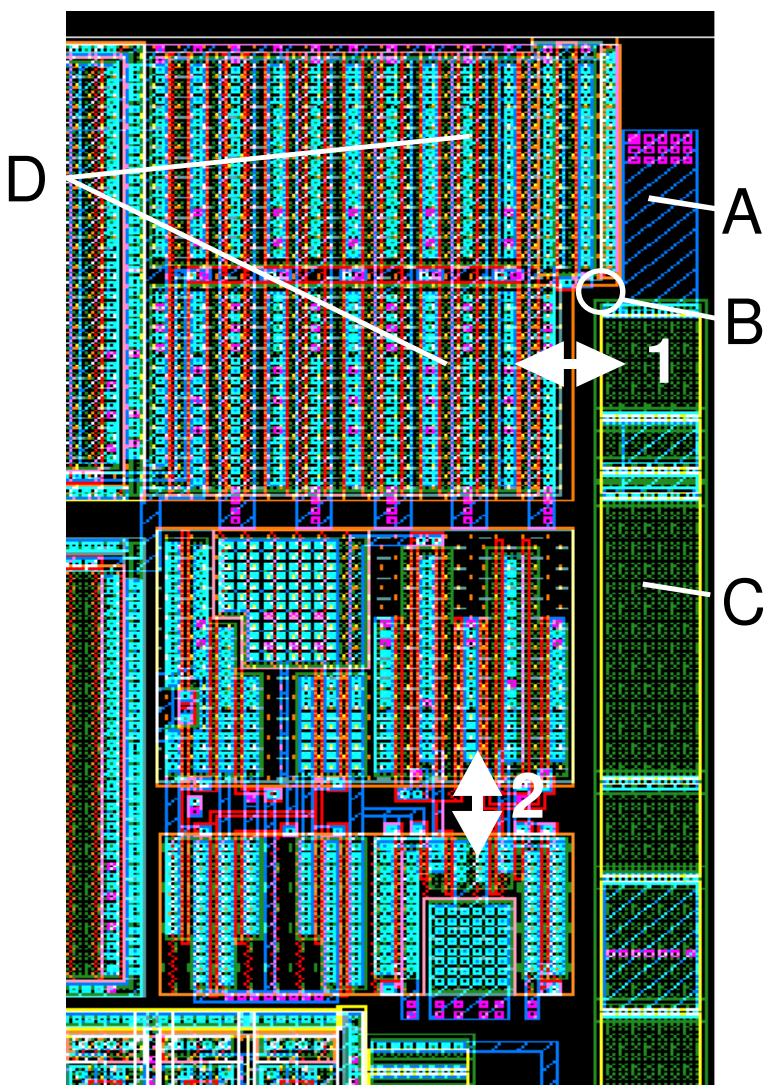
Ground

Latchup Location
Identified by Laser

Resistor

National Semiconductor DS90C031 LVDS

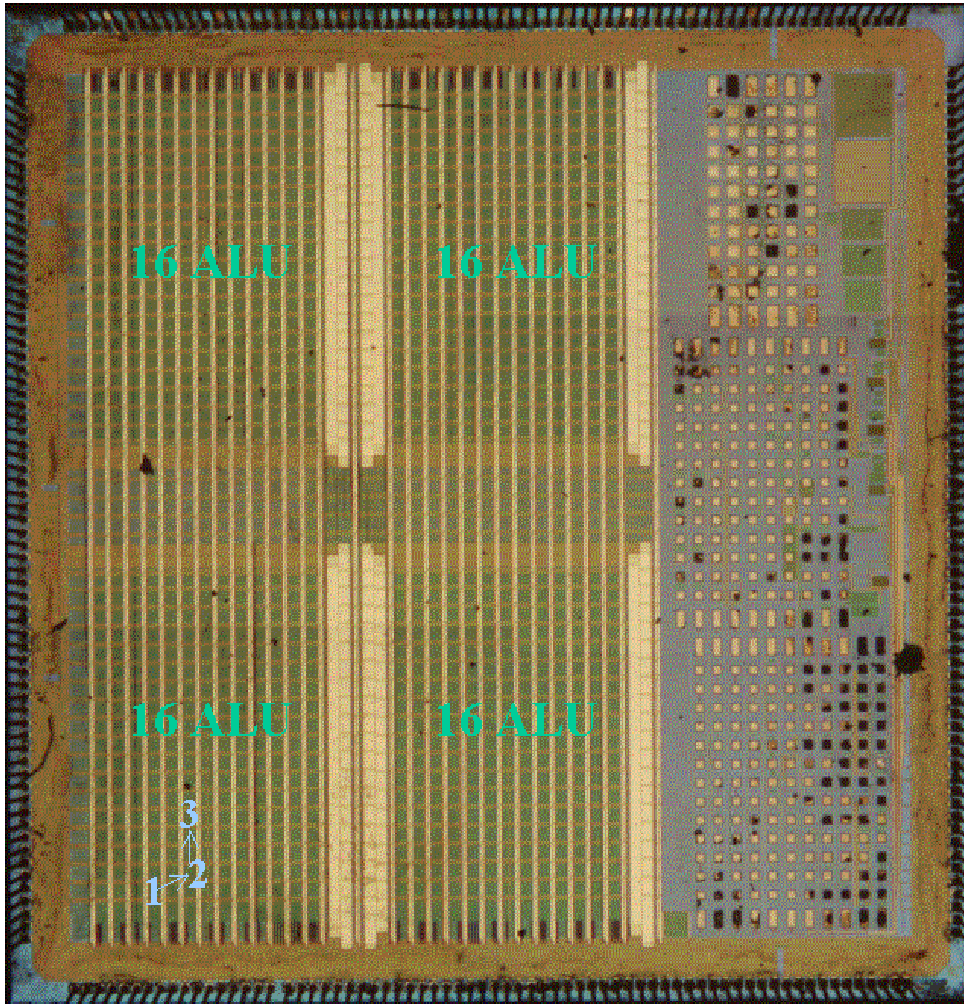
Comparison of Two Designs



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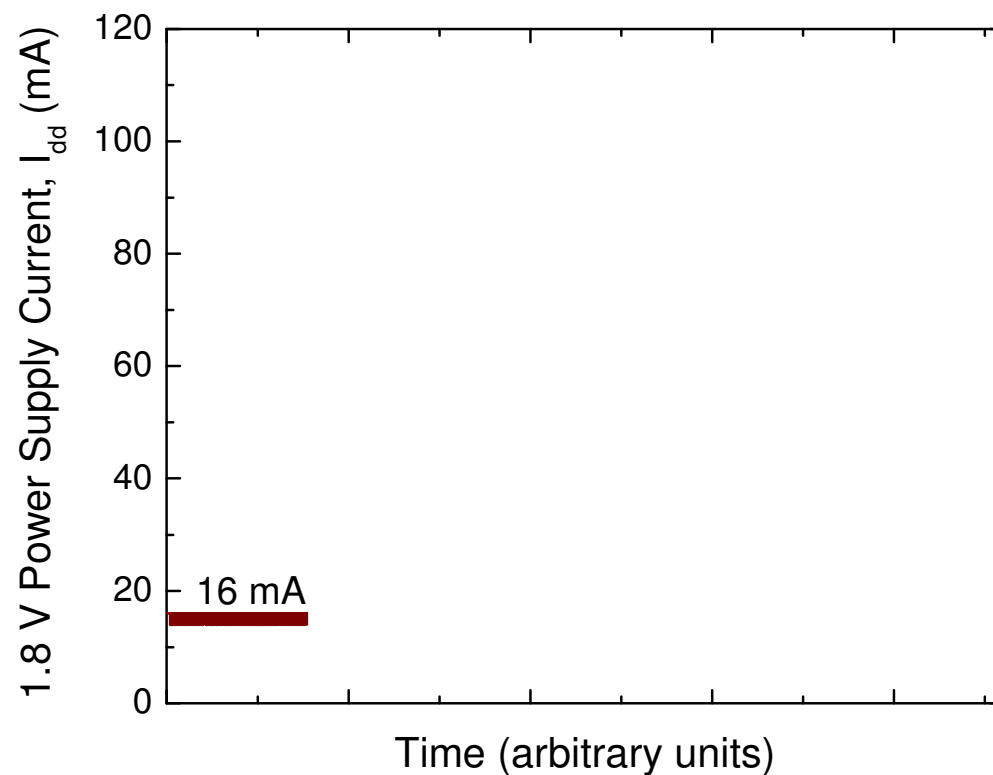
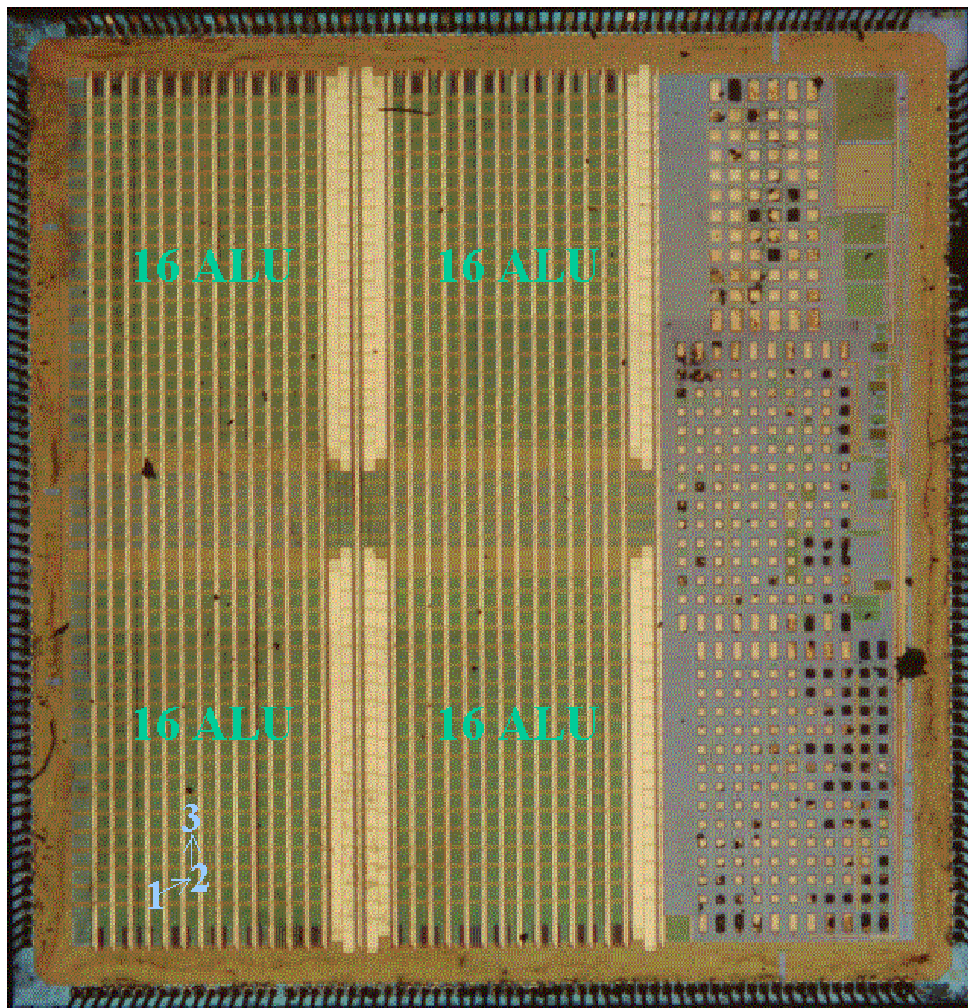
5. LSI Logic ASIC

Micro-Latchup in LSI Logic ASIC

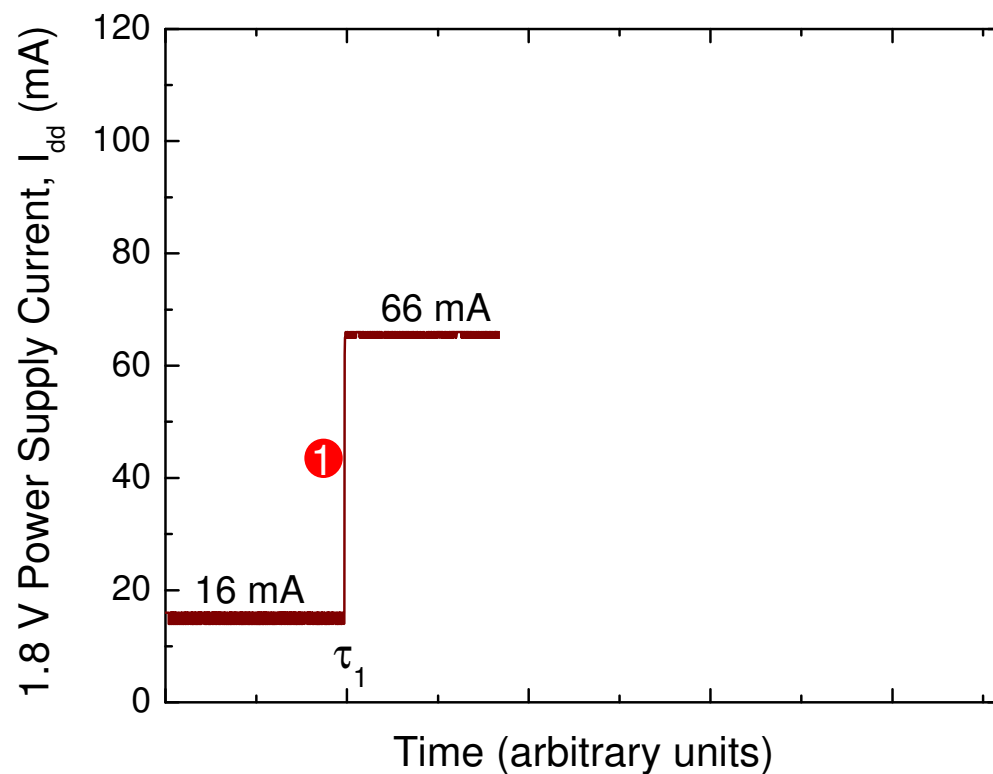
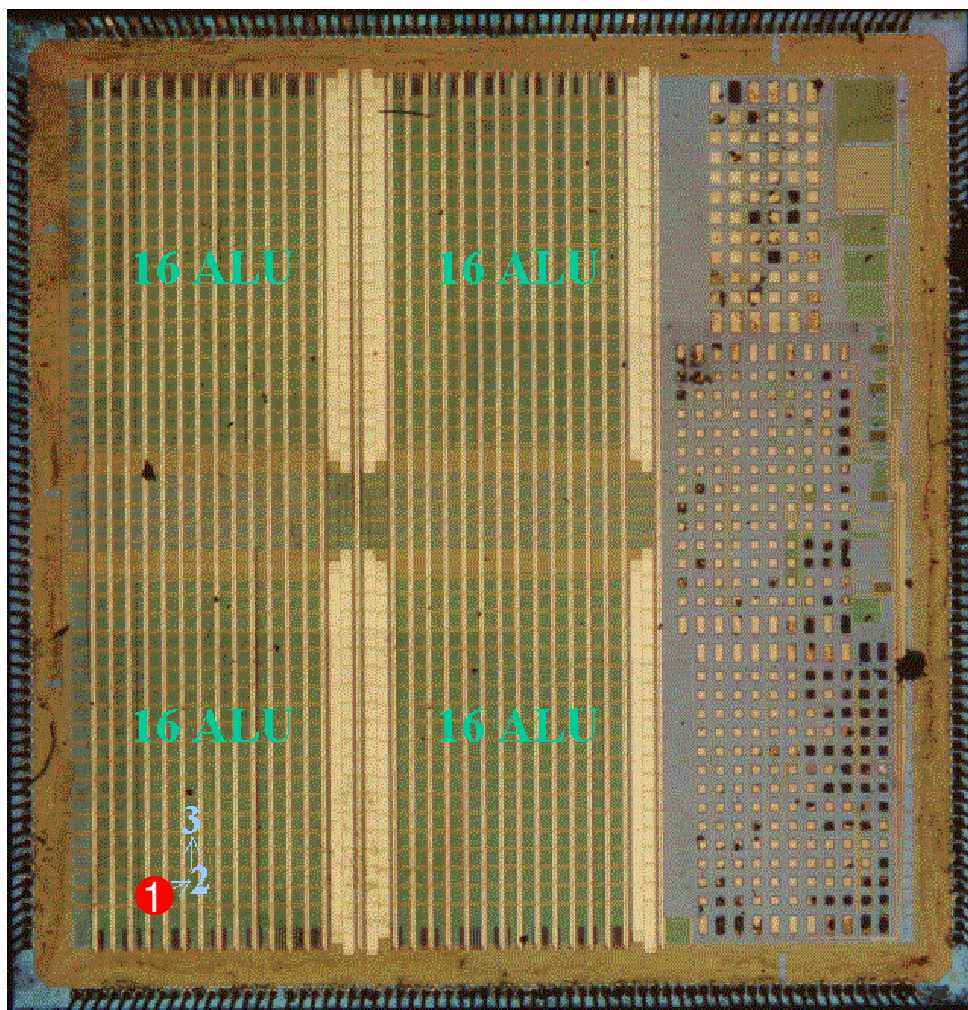


- High-current anomalies observed in HI testing
- Large bursts of errors and device stops functioning for LETs greater than 2.8 MeV·cm²/mg
- Analysis of current records revealed series of jumps of 10 to 60 mA
- Power cycle necessary to recover functionality
- Consistent with Micro-latchup
- Taken to laser for evaluation

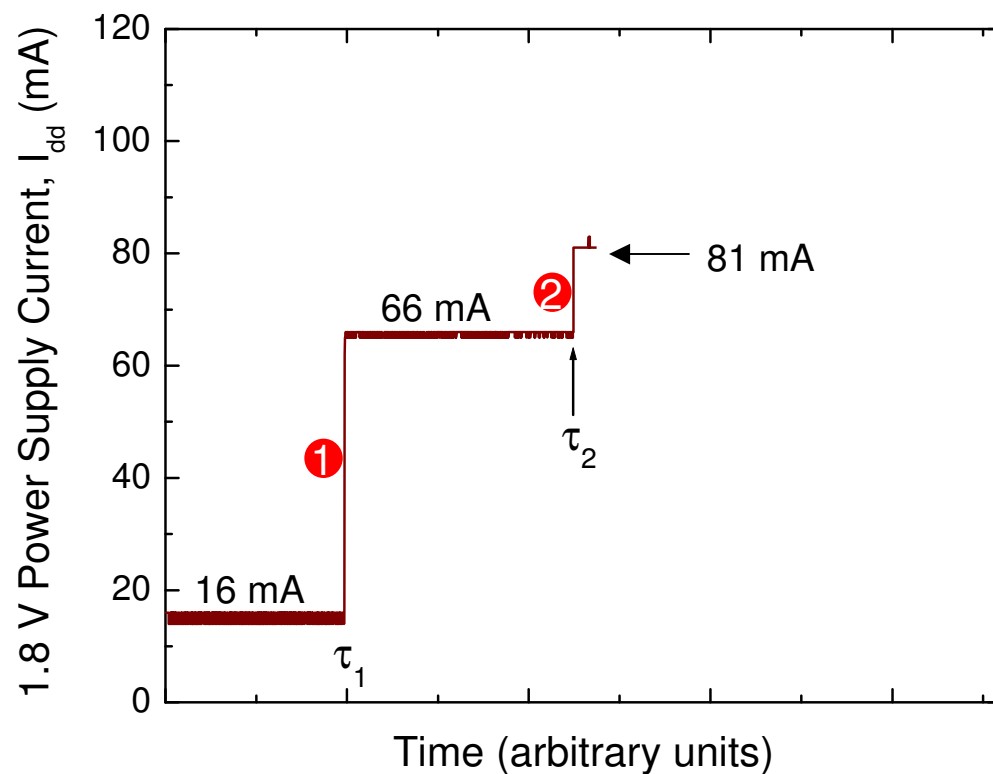
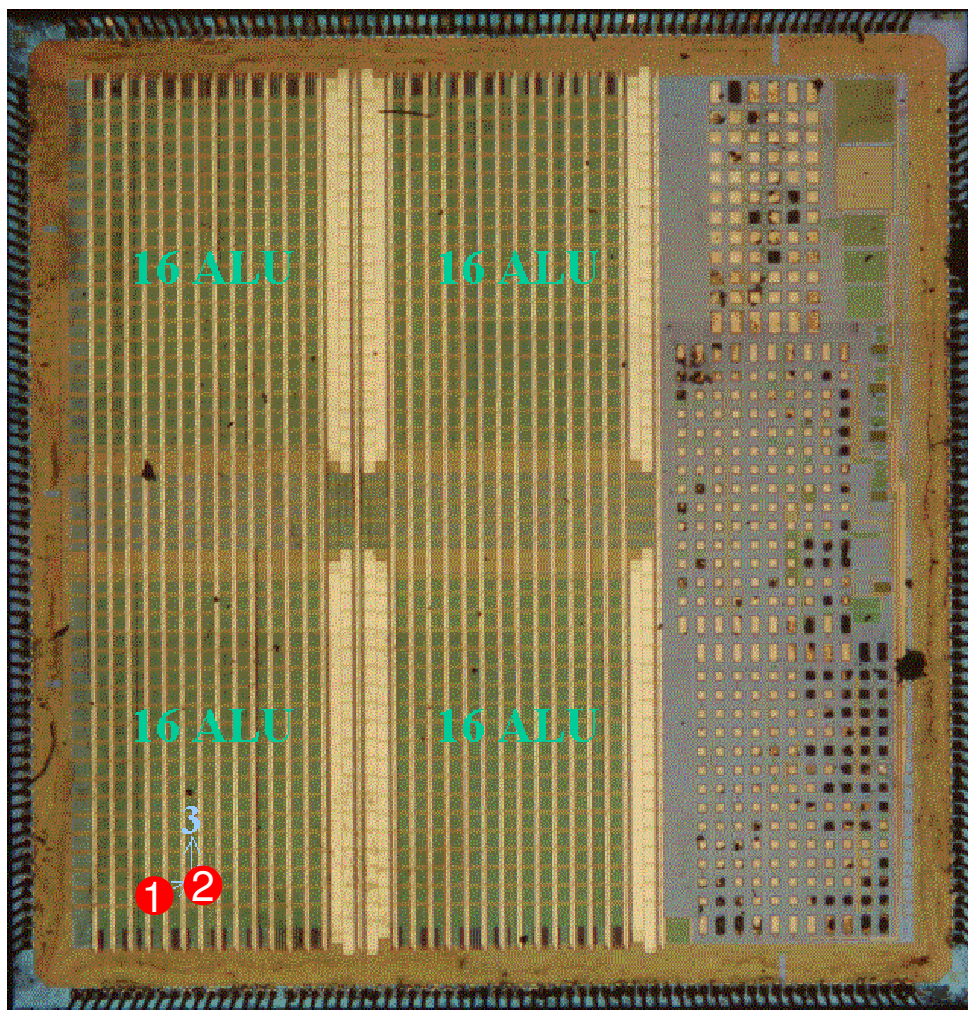
Micro-Latchup in LSI Logic ASIC



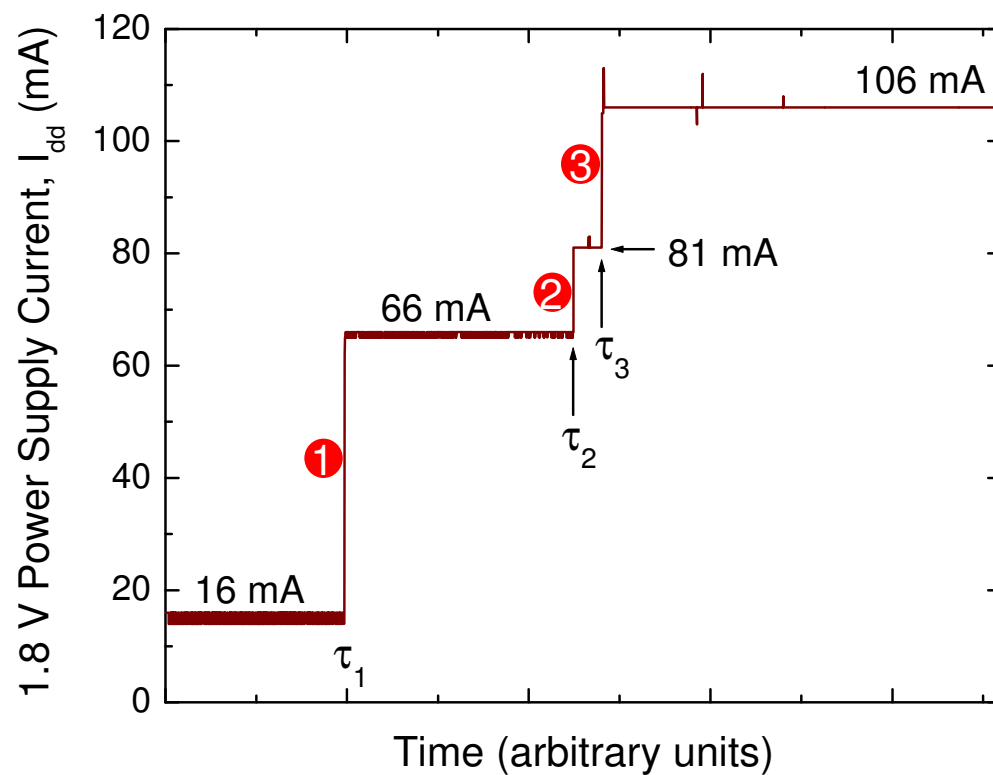
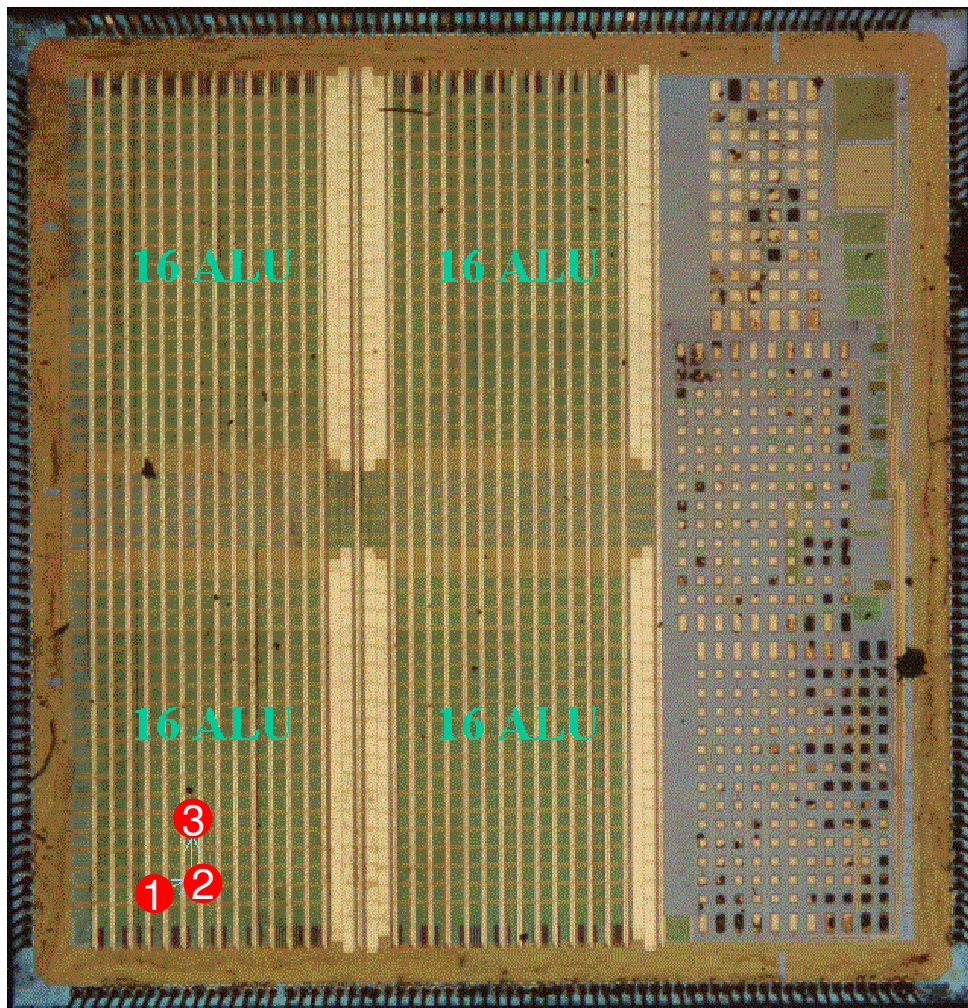
Micro-Latchup in LSI Logic ASIC



Micro-Latchup in LSI Logic ASIC



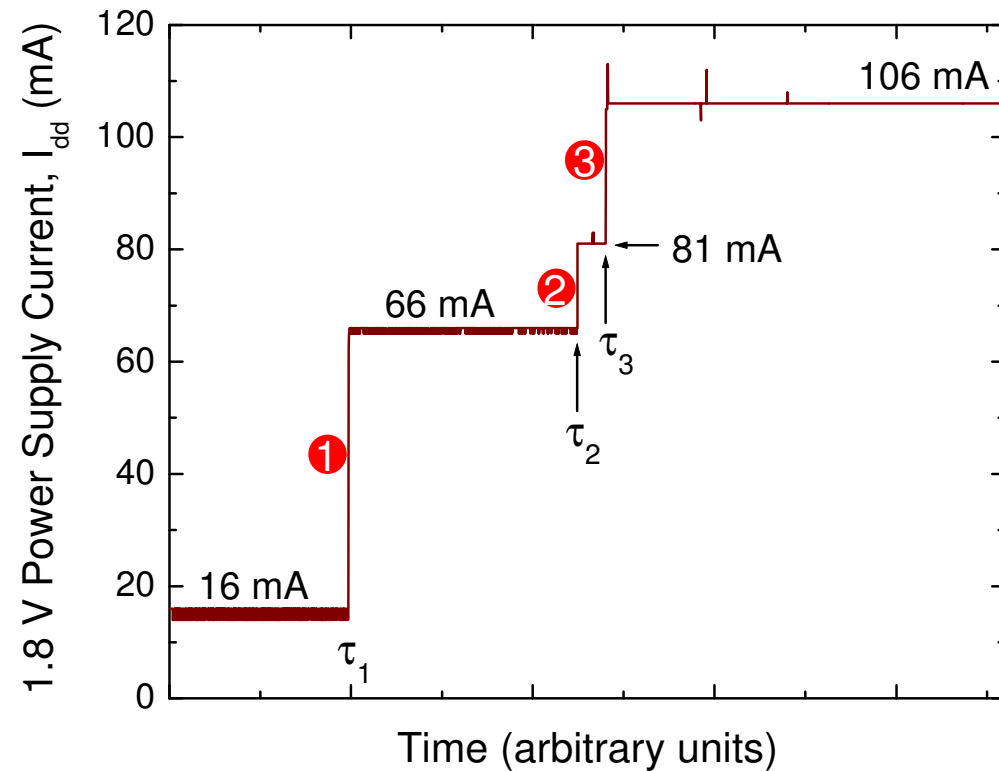
Micro-Latchup in LSI Logic ASIC



Micro-Latchup in LSI Logic ASIC

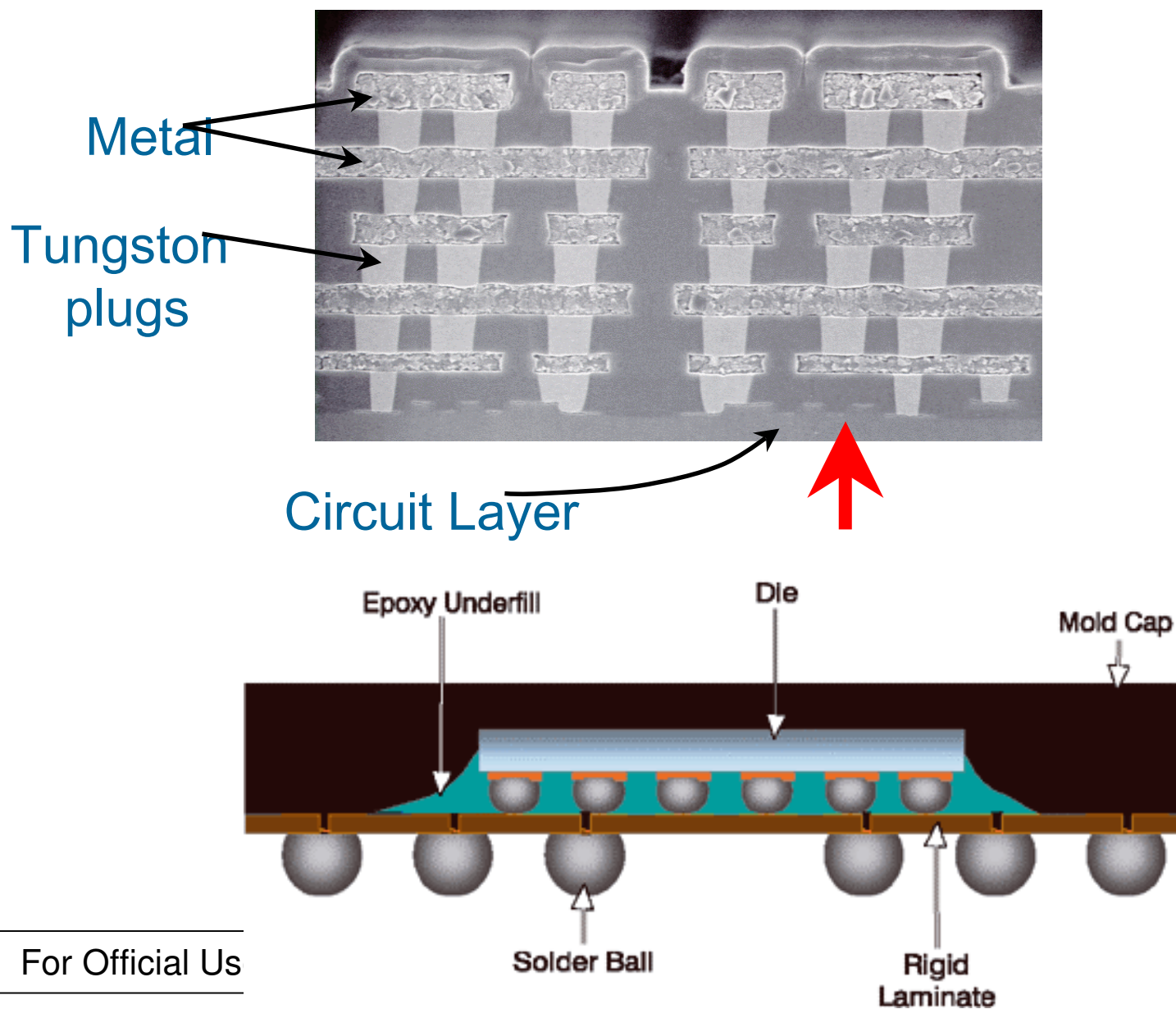
- Complete loss of functionality
- Non-damaging
- Practical ramification:

→ Choice of set-point for power cycling is critical

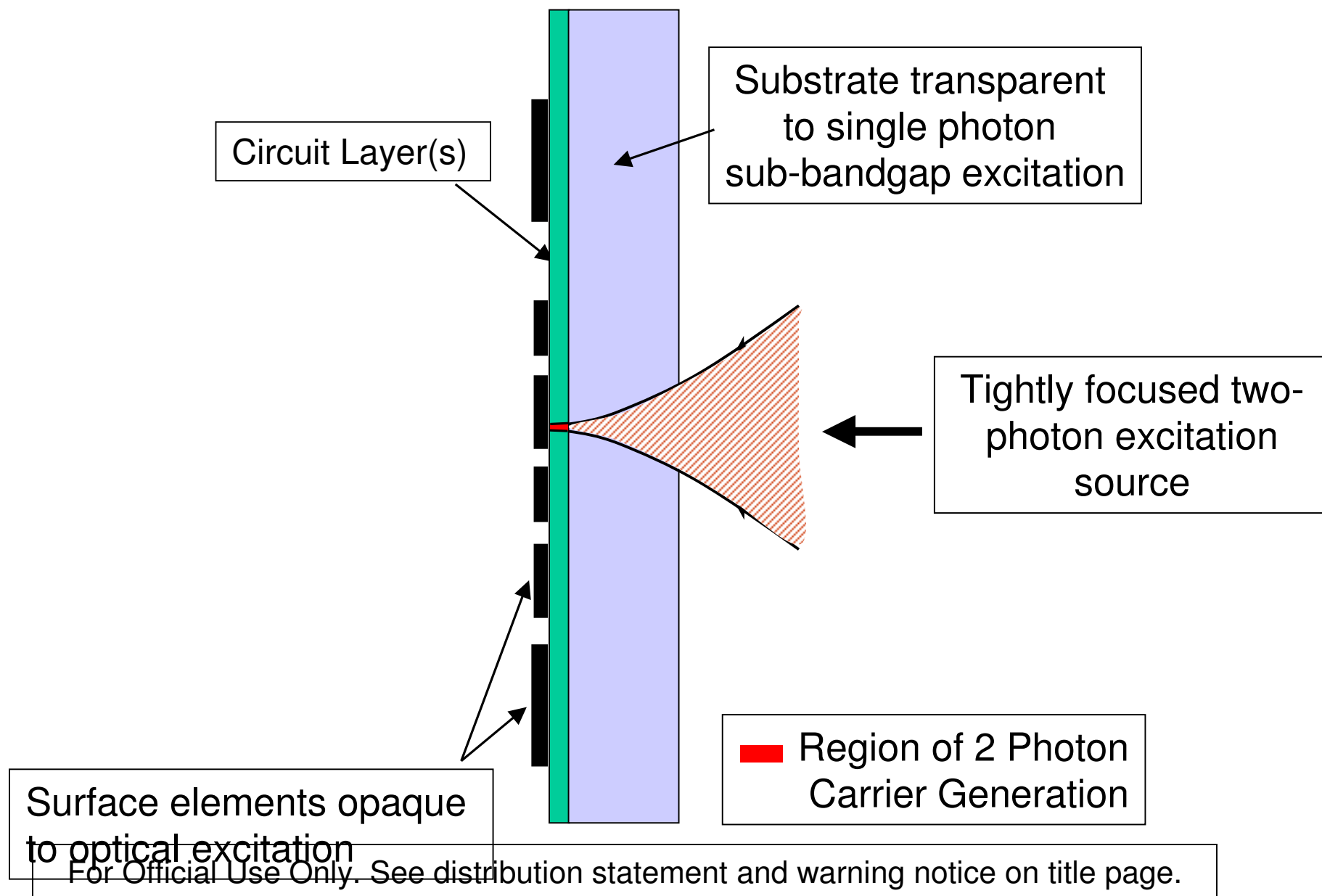


6. Backside Irradiation

Cross Section of Modern Device



Backside “Through-Wafer” TPA



Two-Photon Absorption SEE Experiment

- The technique has been used successfully for producing single event upsets in an SRAM and single event transients in an operational amplifier.
- The next step is to demonstrate that it can also produce latchup when incident from the backside.

Summary

- Discussed the type of information that can be gained from pulsed laser SEL studies
- Several case studies:
 - screening
 - identification of sensitive areas
 - clarification of specific processes
 - latent damage
 - examples in which the information gained is used to redesign the part to eliminate susceptibility.
- The role of two-photon absorption